Successful Return to Flight of the H-IIA Launch Vehicle

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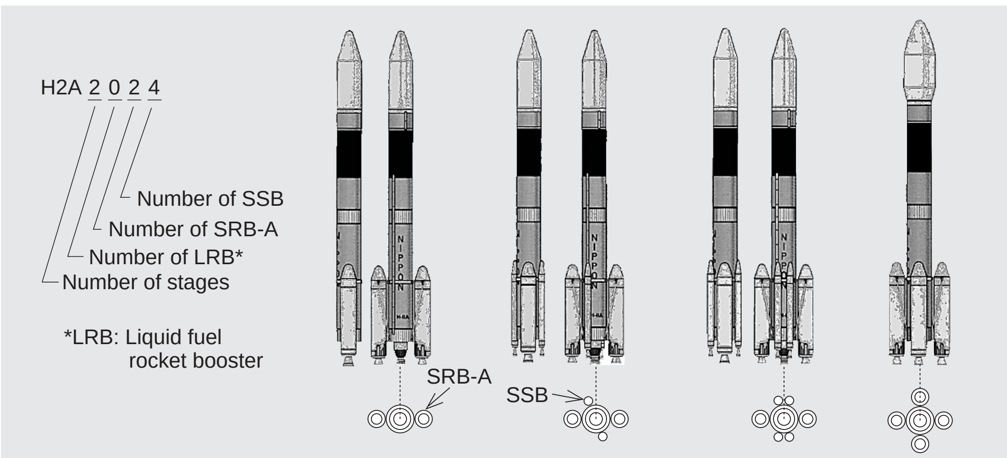
Since the failure of H-IIA flight No.6 in November 2003, launch of H-IIA had been suspended. To make H-IIA launch resume through lessons learned from this failure, corrective actions were taken not only to improve the cause of failure itself but also to improve the H-IIA reliability through re-evaluation of overall H-IIA development process. Then the improved H-IIA was launched on February 26,2005 and returned to flight successfully. This paper describes the activities for the return to flight of H-IIA and the results of the flight.

1. Introduction

H-IIA is the Japan's workhorse launch vehicle that is able to carry four ton class satellite into geosynchronous transfer orbit (GTO). The rocket is two stage vehicle and has Solid Rocket Boosters (SRB-A) which are mounted on the lower section of the first stage. Additional 2 or 4 smaller Solid Strap on Boosters (SSB) are able to be attached on the first stage depending on the launch capability requirement from satellite. The H-IIA launch vehicle has several variation by number of SRB-A and SSB as the satellite demands (**Fig. 1**).

H-IIA was launched five missions successfully after its maiden flight on August 29, 2001. However H-IIA Flight No.6 on November 29, 2003 was failed. The investigation revealed that the accident cause was hot combustion gas leakage resulted from a hole formed on eroded nozzle of SRB-A which located on the right side of the H-IIA vehicle. To overcome this accident and to make return to flight, activities were carried out, which are not only to correct the nozzle but also to improve the whole of the H-IIA launch vehicle. These activities were performed by re-evaluation back to basic design and development process of H-IIA launch vehicle and picked up corrective actions which improved the H-IIA reliability. These corrective actions were implemented to the vehicle waiting for return to flight. After all these activities, the improved H-IIA launch on February 26, 2005 was successful to carry the satellite to geo-synchronous orbit.

This paper reports on the activities toward the return to flight of H-IIA overcoming the Flight No. 6 accident and the result of the flight.



Configuration	H2A 202	H2A 2022	H2A 2024	H2A 204
Launch capability (GTO)	4.1t	4.5t	5.0t	6.0t

Fig. 1 H-IIA launch vehicle family This figure shows the H-IIA launch vehicle family

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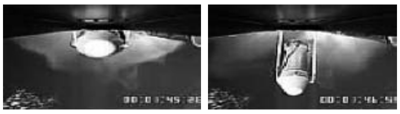
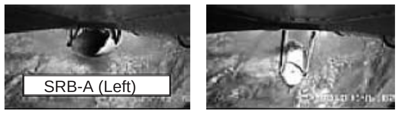
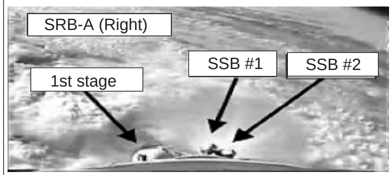
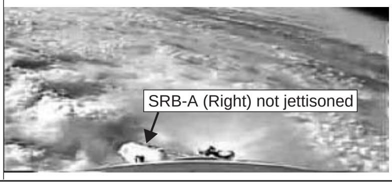
Camera	Flight No. 5	Flight No. 6
No. 0 Camera Lift-off + 106 sec. SRB-A (Left) separation		
No. 1 Camera Lift-off + 98 sec. SRB-A (Right) burn out		
No. 1 Camera Lift-off + 106 sec. SRB-A (Right) separation SSB #1 separation		

Fig. 2 Photos by on board CCD cameras The condition of rocket No. 6, whose SRB-A was not jettisoned, is shown as compared with that of rocket No. 5, whose SRB-As were jettisoned normally.

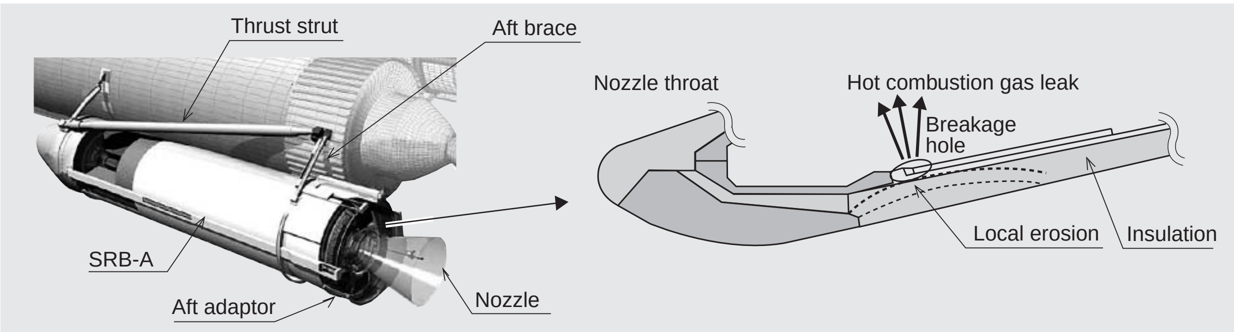


Fig. 3 Cause of the Flight No. 6 accident The figure shows the cause of the flight No.6 happened in the SRB-A nozzle.

2. Flight No.6 accident

H-IIA Flight No. 6 was launched from Tanegashima Space Flight Center at 13:33 on November 29, 2003. The vehicle followed it's planned flight path before SRB-As separation. At 105 sec. after lift-off, right side SRB-A did not jettisoned though the SRB-A separation signal was sent from the guidance computer mounted on the first stage (**Fig. 2**).

The vehicle velocity became less than the planned value, though the following events, such as SSBs separation, the fairing jettison, 1st and 2nd stages separation and 2nd stage engine ignition, were performed. The destruct command was send at 13:43:53 (10 minutes 53 seconds after lift-off) because there became little chance that the vehicle gained the altitude and velocity needed to carry the satellite to the planned orbit. The 2nd stage and satellite fell into the Pacific Ocean.

The accident investigation revealed that the malfunction of right side SRB-A separation was caused by hot combustion gas leakage from a breakage hole on the SRB-A nozzle which was formed by local erosion of nozzle inner insulation. The cause of failure identified by accident investigation is as follows (**Fig. 3**):

(1) Local erosion of the inner CFRP insulation of nozzle, by a combustion gas jet, formed a breakage hole on the nozzle
(2) Hot combustion gas leaked through the hole on the nozzle.
(3) The leaked hot gas burned components including detonating fuse responsible for sending separation signal
(4) The signal to jettison the SRB-A was sent but the booster failed to separate.

3. Activities for the return to flight

The following activities were implemented with the aim of the return to flight: (1) Investigation of the root causes of the accident, (2) Re-evaluation of the whole H-IIA launch system, and (3) Verification of the reliability of other contractors products.

(1) Investigation of the root causes of the accident

MHI participated in the activities to investigate the mechanism of the "SRB-A nozzle breakage which made combustion gas leakage" which was the root cause of the Flight No. 6 accident. Besides MHI reviewed the countermeasures and determine the configuration of the improved SRB-A, with the Japan Aerospace Exploration Agency (JAXA).

As a result of the activities, it was decided that the improved SRB-A should incorporate the following measures to prevent local erosion of the nozzle insulation (**Fig. 4**):

- Relaxation of combustion pressure
- Adoption of a bell-shaped nozzle
- Increase of wall thickness of nozzle

These countermeasures were verified by ground firing tests, and accordingly it was approved to apply the improved SRB-A to the return-to-flight vehicle.

(2) Re-evaluation of the whole H-IIA launch system

On reflection from the accident of Flight No. 6, re-evaluation of the whole H-IIA launch system was thoroughly performed into its basic design and development process. This re-evaluation activity collected issues to be assessed in terms of the probability of a risk occurring and the severity of the consequences (**Fig. 5**). This activity picked up 786 potential issues and selected 77 items to be implemented to the return-to-flight vehicle.

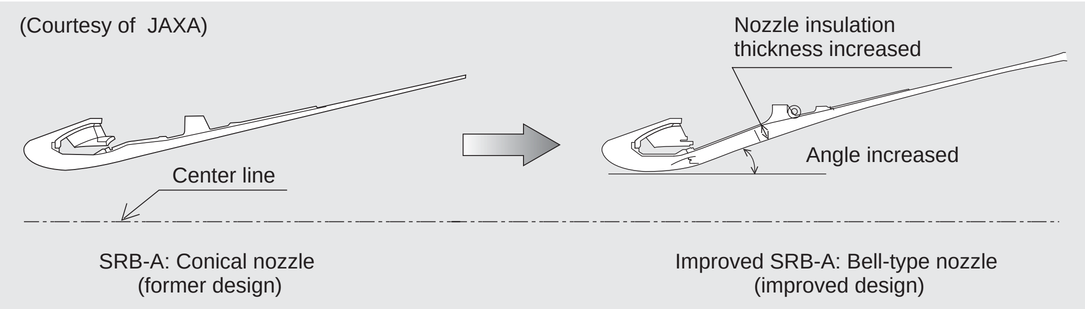


Fig. 4 Improvement of SRB-A nozzle The figure shows the improvements made to the SRB-A nozzle.

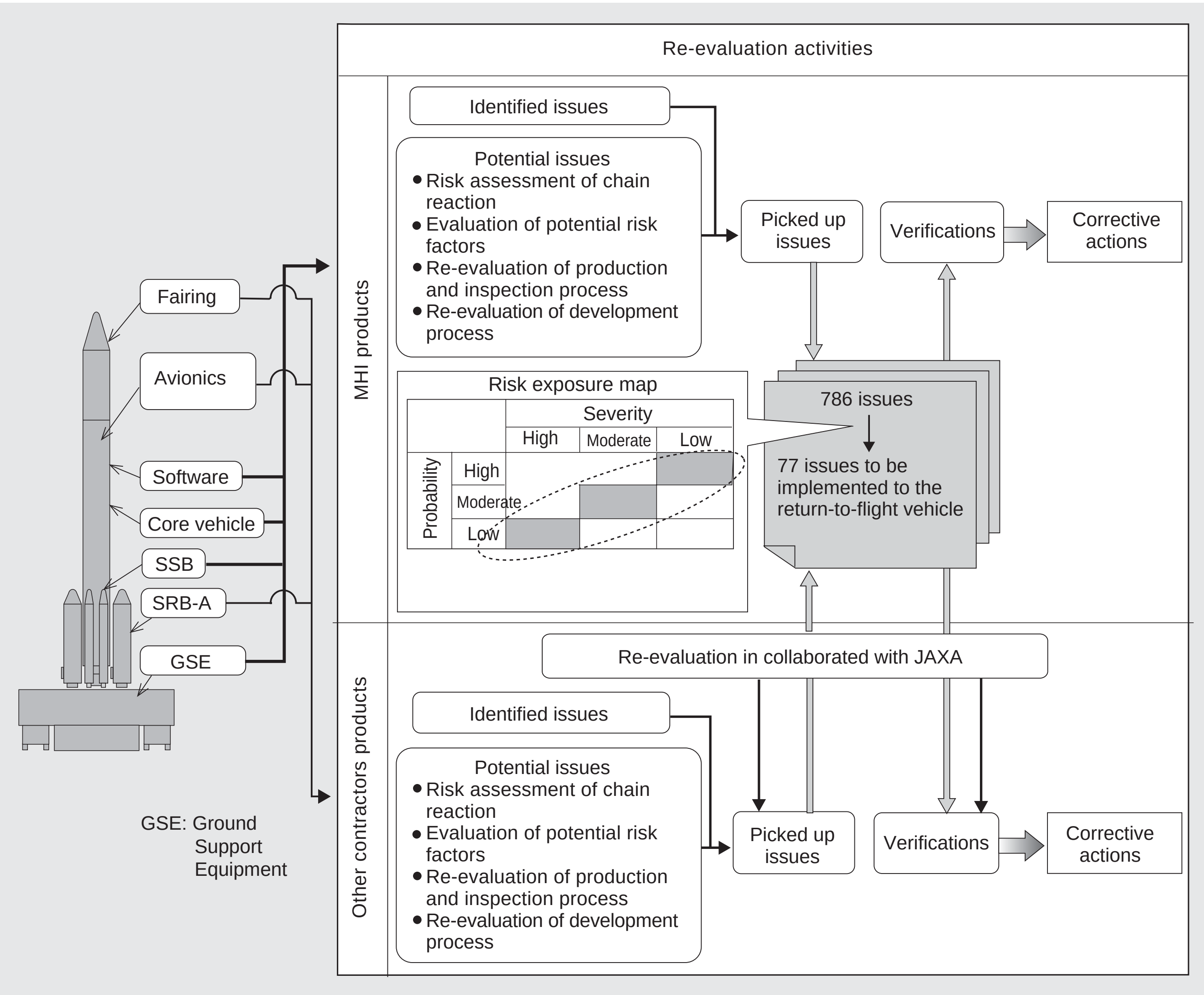


Fig. 5 Flowchart of re-evaluation activities of the H-IIA launch vehicle

For example, following improvements were implemented to H-IIA:

- to protect critical wire harness and detonating fuse adjacent to engines or to change routing of these against potential hot gas leak from engines.
- to reposition critical equipments, fuses and harnesses against potential hot gas leak from SRB-A nozzle.
- to change installation of flight safety instruments.
- to add flight monitor channels.

These improvements applied to the H-IIA launch vehicle resulted to enhance its reliability.

(3) Verification of the reliability of other contractors products

To enhance the reliability of the H-IIA launch vehicle for the return to flight, MHI has carried out activities from the viewpoints of system integrator and manufacturer to verify reliability and quality of other contractors products, such as SRB-A, payload fairing, reaction control system, pyrotechnics, avionics, and so on, which are provided to MHI (**Fig. 6**).

4. Result of the return to flight

H-IIA Flight No.7, which was took the role to return to flight, was launched at 18:25JST on February 26, 2005. The launch vehicle flew smoothly along the planned flight pass (**Fig. 7**), and injected Multi Transport Satellite-1 Replacement (MTSAT-1R) into the target GTO orbit 40 minutes and 2 seconds after lift-off (**Table1**).

The flight telemetry data showed that all systems had worked normally, so it was proved that all corrective actions implemented for the return to flight were appropriate. This success has demonstrated that the H-IIA launch vehicle is a highly accurate and highly reliable launch system.

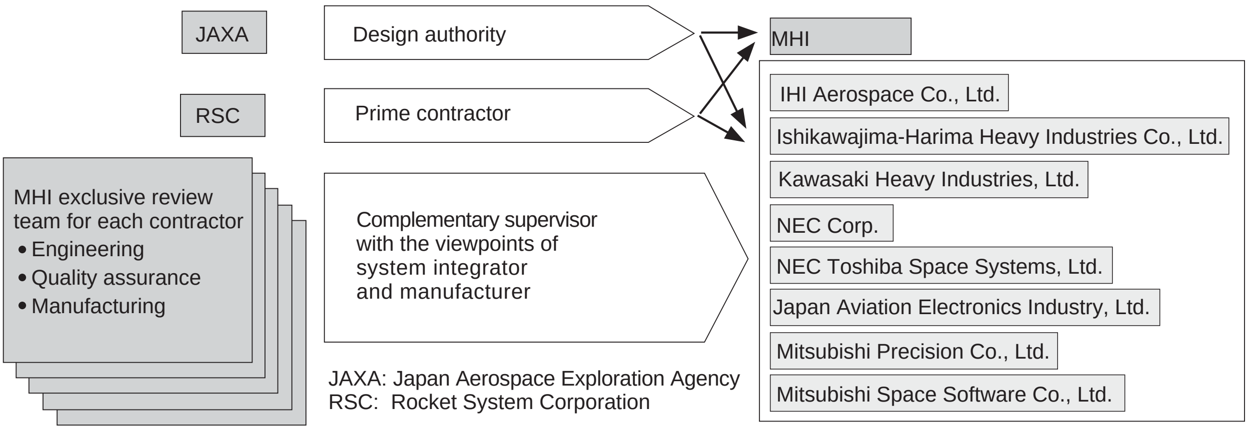


Fig. 6 Activities to verify the reliability of other contractors products

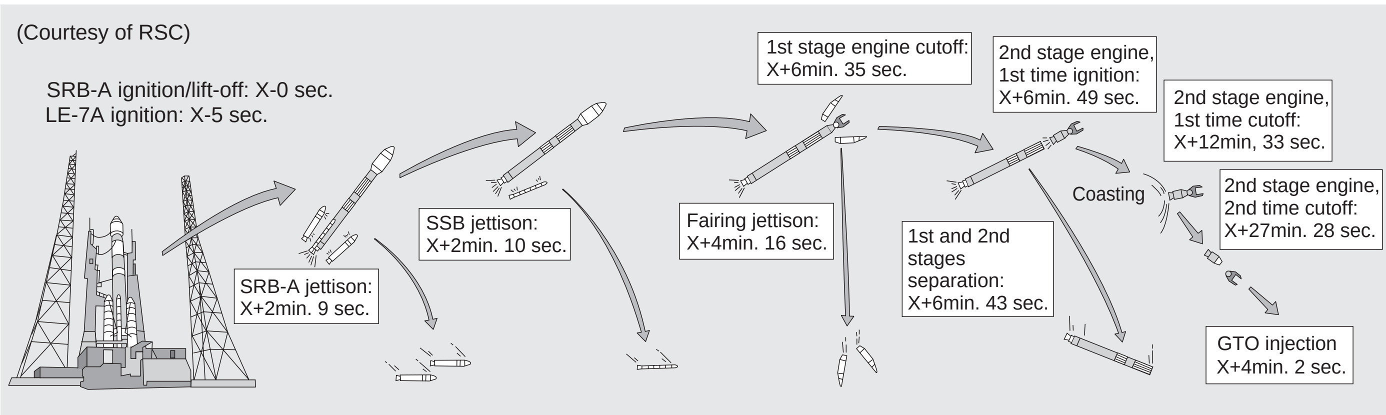


Fig. 7 Flight sequence of H-IIA Flight No.7

Table 1 Result of MTSAT-1R injection orbit

	Target (allowance)	Actual	Deviation
Apogee (km)	35 786 (±180)	35 793	7
Perigee (km)	250 (±4)	249	−1
Inclination (deg.)	28.5 (± 0.02)	28.5	0

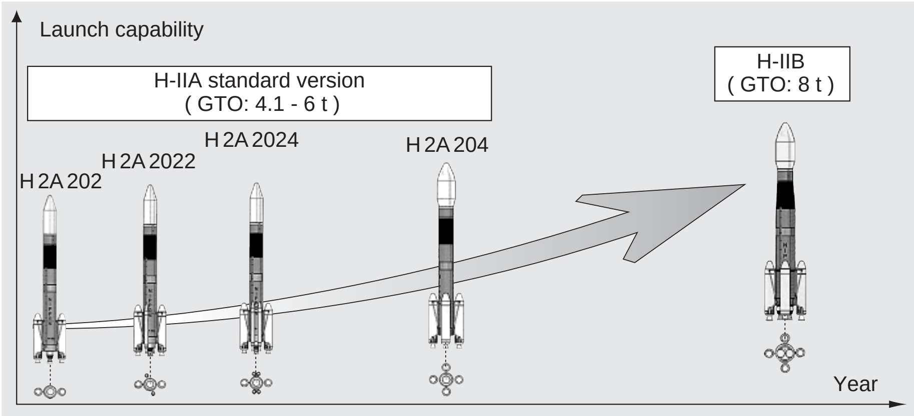


Fig. 8 Development of H-IIA family
This figure shows the development scenario from the current H-IIA standard version to H2A 204 version and enhanced version called H-IIB.

5. Plan for future missions

Future H-IIA launches are planned in and after 2006, such as the launch missions of Advanced-Land Observing Satellite (ALOS), The Multi-Functional Transport Satellite 2 (MTSAT-2) and others. Accomplishments of continuous launch success for these future missions will enhance the reliability of H-IIA launch vehicle, and is expected to result in winning of commercial launch service contracts.

To meet the demand of 6 tons class GTO satellites, such as Engineering Test Satellite VIII, H2A 204 version using four SRB-As is now under development. Though the development of this version was suspended due to the Flight No. 6 accident, the successful return to flight made this development resume. This H2A204 version, which is implemented also corrective actions from the Flight No.6 accident, is scheduled to launch in 2006.

Furthermore in order to meet the demand of carrying the H-II transfer vehicle (HTV) to International Space Station (ISS), the development of H-IIA enhanced version called H-IIB, which has about 5m diameter first stage, has been begun (**Fig. 8**).

6. Conclusion

Circumstances of the H-IIA launch service business is now changing for privatization, and also MHI's business model is changing from one manufacturing contractor to prime contractor of the whole launch vehicle as well as provider of the launch services. The H-IIA Flight No. 6 failure occurred in the middle of this change.

This failure was undeniably a negative factor, but became a chance to enhance the reliability of our launch vehicle. The success of Flight No.7 of the improved H-IIA actually showed the result of activities to improve the reliability of H-IIA launch vehicle.

However, one success is insufficient for the launch service business. Our constant efforts to enhance the H-IIA reliability will make results of consecutive successful launches and will assure the success of the privatization of the H-IIA launch vehicle.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